TABLE V. Comparison of Blackened-bulb Thermometer in Air-pump Receiver with ordinary Blackened-bulb Thermometer *in vacuo*.

Date.	Mean of two b. bulbs *in vacuo*. Corrected.	B.-b. therm. in air-pump Receiver. Corrected.	Diff.
Sept. 12. h m			
11 47	121·9	119	2·9
0 2	122·7	121	1·7
0 6	122·8	121·2	1·6
0 12	123·0	122·5	0·5
0 17	120·9	121·5	−0·6
1 13	121·1	121·5	−0·4
Sept. 16.			
10 0	100	102·5	−2·5
10 20	104·5	107	−2·5
10 30	107·8	110	−2·2
10 40	108·8	111	−2·2
10 44	111·2	112	−0·8
10 48	102·5	105	−2·5
Means	113·9	114·5	−0·6

The discussion on this paper will be found at p. 170.

XVII. *On Temperature in Sun and Shade. An account of Experiments made at Harpenden, Herts.* By the Rev. FENWICK W. STOW, M.A., F.M.S.

[Received December 18, 1872. Read January 15, 1873.]

THIS paper is intended to be supplementary to that on Solar Radiation, already submitted to this Society, and is simply an account of some experiments made in September last.

The object proposed was to determine the effect of different conditions of exposure to radiation upon thermometers of different kinds. A number of instruments were most kindly placed at the author's disposal by Mr. Casella. Of these a set comprising a thermometer with a large bulb, an ordinary verified thermometer, of Mr. Casella's "Kew Observatory" pattern, and another of the same kind, but with the bulb blackened, were placed in each of three positions. One set was exposed to the full rays of the sun at 4 feet from the ground; another was placed on what might be called a zenith-stand *, that is, effectually screened from the direct rays of the sun, and from radiation from the ground, but exposed to the sky in the zenith, and to the whole northern heavens; a third was exposed to less than a quarter of the whole sky, and that only near the northern horizon, placed in fact just as on an open stand of the ordinary construction, only that the body of the stand was much deeper and a little wider than usual, and it was only roughly constructed for the special purpose. Care, however, was taken that the usual conditions of an open stand, including free exposure to currents of air, were not departed from. A set of three maximum thermometers, comprising a blackened bulb *in vacuo*

* The apex of the screen in the "zenith-stand" was 2 feet higher than the bulbs of the thermometers, which were from 1 foot to 1 foot 6 inches distant from it horizontally. The front of this stand was about 3 feet wide, the back being formed of boards leaning against it at an angle of about 45°.

and two ordinary maximum thermometers, one of them with a blackened bulb, was also placed in each of these three positions, and also in a fourth position, where they were exposed to the full rays of the sun, but screened from a large part of the sky by a board about 1 foot square overhanging them at 6 inches distance. Lastly, within a louvre-board screen under a large open shed, the thatched roof of which did not come within 10 feet of the ground on the south side and 7 feet on the north side, was placed a set, including all the above-named instruments except the black-bulb maximum thermometer (not *in vacuo*), with the addition of a wet-bulb thermometer. The thermometer with a large bulb, however, was only placed there for a very short time. All these thermometers were carefully re-verified, and the readings have all been corrected for index-error. The "Kew-Observatory" thermometers were newly verified at Kew, and none of them had an index-error exceeding a tenth of a degree. They were all placed with their bulbs perfectly free, so as to be affected by every current of air; and during the experiments there was always a fresh breeze. This would, of course, tend to produce uniformity in the readings; and it is probable that in calm summer weather the differences would have been much greater. Observations were taken only during the middle of the day, and have been classed according to the state of the sky overhead.

One important result of the experiments may be briefly stated thus:—Different thermometers do not agree either in the sun or the shade, unless all sources of radiation and reflection are cut off, as when protected by the louvre-board screen. The thermometer with a bulb 0·56 inch in diameter read 2° or 3° higher in the sun than the "Kew-Observatory" thermometer with a bulb of 0·4 inch diameter; 0°·3 higher on the zenith-stand, and 1° higher on the open stand; but a few observations within the louvre-board screen gave a reading 0°·2 lower than the other. It is not evident why a large bulb, when exposed to radiation, should read higher than a small bulb. Possibly it is because the glass is thicker, as ascertained by the experiments of Mr. B. Loewy, referred to in the previous paper, and therefore more heat is absorbed. But as the large-bulb thermometers were not mounted precisely in the same manner as the others, the experiment should be repeated with unmounted thermometers. The porcelain scale of the large-bulb thermometers came within about 0·5 inch of the bulb; and, though the bulb was perfectly free, the scale may have become hotter than the bulb, and radiated heat to it. The indication of the thermometer with blackened bulb exceeded that of the ordinary thermometer by 6° in the sun, about 1°·2 on the zenith-stand, and from 0°·8 to 1°·7 on the ordinary stand. A thermometer with spirit coloured red, which was tried on the stand, indicated 0°·9 higher than the "Kew Observatory." Of the maximum thermometers, the blackened bulb *in vacuo* (which may be called the solar thermometer) exceeded the ordinary maximum by 10° on the zenith-stand, and 4° on the ordinary stand; while within the screen it fell 0°·2 below it, probably owing to its being less sensitive. Comparing next the temperatures marked by the similar "Kew-Observatory" thermometers in the different positions, it was found that with full sun and zenith clear, it was only

3°·4 hotter in the sun than in the louvre-board screen; but with the zenith overcast it was 5° hotter, and with the sky hazy 3°·7. On the zenith-stand it was 0°·5 warmer than in the screen when the sky was clear, but 1°·5 when overcast in the zenith, 0°·8 when hazy, 1°·1 when nearly overcast. On the open stand it was 1°·2 warmer than in the screen when the sky was clear, 1°·4 when it was overcast in the zenith, 0°·9 when hazy, and 0°·6 when nearly overcast. The ordinary maximum thermometers read 4° higher in the sun than within the screen; and this excess was increased to 5° by screening the zenith; diminished to 1°·5 on the zenith-stand, but on the ordinary stand it was no less than 3°·6. The thermometer used on this stand was one by Negretti and Zambra, made more than fourteen years ago, and which previously scarcely ever differed more than 0°·1 from the Phillips's maximum thermometer placed in the screen, when both were in a louvre-board screen together. It had a larger bulb than the other unblackened maximum thermometers, and was mounted while they were not.

These figures indicate some facts worthy of remark. First, with regard to the zenith-stand, it appears that when the sky is nearly clear the small portion of the reflected rays, which a bright mercurial bulb absorbs, scarcely more than counterbalances at noon in September the heat radiated from the bulb into space. But when the zenith becomes overcast, or nearly so, on a fine day the thermometer on the zenith-stand marks a degree or two above the temperature of the air, showing that the solar heat received from the clouds exceeds the diminished effect of the bulb's own radiation by that amount. In the next place, by cutting off the greater portion both of this reflected heat and of the bulb's own radiation, but, at the same time, admitting radiated or reflected heat from the ground, the temperature is not lowered but raised, the only exception being when the reflection from the clouds is at its maximum, owing to the zenith being overcast with bright cumuli; in which case the excess of cloud-reflection over radiation into space nearly equals in amount the radiation from the ground. In short, the temperature of a thermometer placed on an ordinary open stand is raised above the temperature of the air, not so much by the reflection from the small portion of the sky to which it is exposed, as by radiation or reflection from the ground. But as there cannot be much reflection from green grass, the effect must be principally due to radiated heat.

In order, however, to establish this conclusively by a more direct experiment, two similar verified "Kew-Observatory" thermometers were placed on the open stand, exactly as the dry- and wet-bulb thermometers are usually placed; but 1 inch below the bulb of one of them a board of a dull colour was fixed, to intercept the radiation or reflection, if any, from the ground, without any appreciable amount of the heat from the clouds being reflected from the board to the bulb. Two other "Kew-Observatory" thermometers were also placed inside the stand, both screened from the whole sky, but one exposed to heat-rays proceeding from the ground, and the other sheltered from them. It was now late in September, and rain had fallen, making the ground much colder than it had previously been. Still it was found that of the two first, the thermometer screened

from the ground read 0°·6 lower than the one not so screened, and in the case of the two latter the difference was 0°·9, the thermometer screened from both sky and ground reading nearly the same as that in the louvre-board screen. The effect of screening the portion of sky to which the two first thermometers were exposed was less considerable. When the sky was less than half overcast the temperature was thereby raised 0°·15, and when more than half overcast it was depressed 0°·34.

It follows therefore that the excess of temperature indicated by a thermometer on an ordinary open stand over that shown by one in a louvre-board screen is mainly the result of radiation from the ground, the rays from which, being almost wholly obscure, are readily absorbed by the glass of the bulb, whereas the solar rays reflected by clouds, being of much greater refrangibility, are most of them transmitted through the glass, and reflected from the bright surface of the mercury. Indeed, remembering that the thermometers in full sun were affected, not only by direct solar radiation, but by reflection from clouds and radiation from the ground, it is possible that in summer an ordinary thermometer, placed at 4 feet above the surface, acquires more heat from the ground than even from the direct rays of the sun at noon. This explains how it is that the excess of maximum temperature on an open stand above that registered within a screen is greatest in summer, when the ground is very much hotter than the air, and nearly vanishes in winter, when even in the middle of the day the ground is no warmer than the air. But, while a bright mercurial bulb is a very bad absorbent of rays of great refrangibility, the solar thermometer, on the contrary, is very sensitive to their influence *. Hence the sun's rays reflected from clouds were found to raise the temperature of the solar thermometer on the zenith-stand some 10° or 11°. And again, if exposed to the sun, but screened from the bright clouds overhead, it was found to read more than 4° *lower* than if not so screened, although an ordinary thermometer by its side, whether blackened or not, rose 1°, the loss of reflected heat being in this case masked by the gain resulting from the interception of the bulb's own radiation. (See Table V., A & E.) Suppose the whole effect of the latter to be 3° on both instruments, then that of reflected heat on the ordinary thermometer was 2°, and on the solar thermometer was $4°+3°=7°$, or about $\frac{1}{8}$ of the total solar radiation. This reflected heat appears to account for the increase of solar radiation which may be observed, either with a solar thermometer or an actinometer, whenever a bright cloud is approaching the sun, and, partially, for the smaller amount of solar radiation on cloudless days than on days when there are cumuli. It must be remembered, however, that on cloudless days it is often hazy.

The conclusions to be drawn from these experiments have gone quite beyond the immediate objects at first in view. It was evident that a

* The solar rays pass through the external glass and affect the bulb directly; but, being there converted into obscure rays to which glass is opaque, they must first be radiated to the glass and then pass by conduction to its outer surface before they can finally escape. These instruments, therefore, are powerfully and rapidly affected by the sun's heat, but by other influences more slowly, and not to a greater extent than an ordinary thermometer.

thermometer with a blackened bulb not *in vacuo*, if raised above the ground, gave a much better test of the strength of the wind than of the heat of the sun. It was evident also that for the purpose of measuring solar radiation, it did not much signify whether the shade-temperature used was that on an open stand or in a louvre-board screen, but that it ought to be one or the other; and it will be necessary to wait for the Strathfield Turgiss experiments for figures by which to reduce one to the other. The results of these experiments have, however, a more general interest. Without attempting to anticipate the verdict of competent authorities based on the elaborate and exhaustive experiments at Strathfield Turgiss, the author would just point out two facts which his experiments have decided. First, that thermometers with bulbs possessing unequal radiating properties do not agree if placed on an open stand, but do agree most exactly within a louvre-board screen; that is to say, that thermometers containing coloured spirit will not agree with those containing mercury; and, what is still more important, a bulb covered with muslin will not agree with an uncovered bulb. On an open stand the wet bulb is affected by radiation differently from the dry bulb, and must, if the muslin be allowed to become dry on a fine summer's day, read higher than the dry bulb. Any one can verify this result for himself, which was observed by the author long before he suspected the reason. Secondly, that it is impossible for thermometers on an open stand to show the true temperature of the air, since their temperature is raised in the daytime, by radiation from the ground, to an extent depending upon the difference of temperature between the ground and the air, and is also affected somewhat by the state of the sky. At night, on the contrary, their temperature is depressed below the air-temperature; which is proved by the occasional deposition of dew and hoar-frost upon them. In sunny weather, when there is snow on the ground, the maximum temperature is much higher on an open stand than within a screen, owing no doubt to reflection from the snow.

Open stands have done good service; but it is difficult to see why they should continue to be used, unless for the purpose of comparison with old observations. The opinion of an individual observer is a matter of very little moment; but there would seem to be sufficient reasons for a preference for a louvre-board screen.

The stands were visited, and the thermometers read, in the order in which they appear in the Tables. As most of the observations were taken at the time of the day when the temperature is upon the whole nearly stationary, it was not considered that any thing would be gained by incurring the inconvenience of altering the order. They were read by one person, and the figures put down by another, the time occupied in reading being about a minute. When all had been read, those first read were again examined, and if much change had occurred the observation was rejected; if but little, another reading was taken in the reverse order, and the mean of the two counted as one observation. The self-registering thermometers were read afterwards, when necessary. The instruments were generally exposed before 10 A.M. and removed at 4 P.M.

Thermometers of Different Kinds and under Different Conditions of Exposure.

TABLE I. With full Sun and Zenith clear.

Date, 1872.	No. of Obs.	A. Thermometers exposed to full sun.			B. Thermometers screened from sun and ground, but exposed to zenith and northern sky.			C. Thermometers screened from sun and from ¾ sky.				D. Complete shade of louvre-boards under shed.			Cloud.		Wind.
		Large bulb.	Ord.	Black bulb.	Large bulb.	Ord.	Black bulb.	Large bulb.	Ord.	Black bulb.	Red spirit.	Ord.	Black bulb.	Wet.	Amount.	Character.	Hourly Velocity.
		°	°	°	°	°	°	°	°	°	°	°	°	°			miles
Sept. 2, noon	4	78·2	75·7	82·7	71·6	71·4	72·6	73·6	73·3	74·2	74·3	71·1	71·1	62·5	3	cum.	15
„ 5, 11 A.M.	2	75·6	73·5	81·3	69·7	69·6	70·9	70·9	69·9	72·2	71·1	68·1	68·3	61·4	3	cum.	14
„ 6, noon	1	73·6	72·0	78·0	68·4	67·9	69·1	69·4	68·4	70·1	69·4	67·6	67·8	60·9	5	cum.	19
„ 6, 12.15 and 12.20...	2	73·6	72·2	78·5	69·4	68·9	70·1	70·2	69·1	70·7	70·3	68·3	68·3	61·2	4	cum.	21
„ 6, 12.25 and 12.30...	2	75·4	73·6	80·2	69·8	69·5	70·7	70·8	69·7	71·5	70·2	68·6	68·6	61·3	3	cum.	21
„ 7, 3.45 P.M.	1	68·6	67·5	71·0	66·4	66·1	66·6	67·9	66·9	67·9	67·6	66·5	66·5	59·7	1	cir.	23
„ 12, 1.10 P.M.	1	[75·4]	73·5	79·0	71·3	71·1	72·6	72·7	71·9	73·6	[72·8]	70·6	70·7	63·5	4	cum.	23
„ 13, 11.52 A.M.	1	[75·7]	73·8	79·0	72·3	72·1	73·1	75·4	73·1?	76·1	[74·0]	71·3	71·9	66·5	4	cir. c.	10
„ 13, 3.25 P.M.	1	[77·5]	75·0	78·5	74·3	74·1	75·1	75·9	74·9	76·3	[75·8]	74·0	74·0	65·9	4	cum.	11
Mean of 9 observations ...	...	74·84	72·98	78·69	70·35	70·07	71·20	71·86	70·80	72·51	71·72	69·56	69·68	62.54	3·4	...	17·4

TABLE II. Full Sun and Zenith Overcast.

Sept. 2, 2.30 P.M.	1	80·3	76·0	81·7	73·3	72·6	72·6	74·4	73·4	74·6	...	71·9	72·0	63·4	6	cum.	15
„ 5, 10.45 A.M.	1	73·0	71·3	78·5	68·3	67·9	69·4	68·4	67·3	68·9	...	65·9	66·1	60·4	4	cum.	14
„ 5, noon	1	76·8	75·0	82·0	72·3	71·6	72·9	72·4	71·1	72·6	...	69·3	69·3	61·1	5	cum.	18
„ 6, 12.10 P.M.	1	73·5	72·0	78·0	69·6	69·1	70·6	69·9	69·1	70·9	...	68·1	68·1	60·9	5	cum.	21
Mean of 4 observations ...	...	75·90	73.78	80·05	70·88	70·30	71·38	71·28	70·22	71·75	...	68·80	68·88	61·20	5	...	17

Table III. Sun Shining, but Sky Hazy.

Date, 1872.	No. of Obs.	A. Thermometers exposed to full sun.			B. Thermometers screened from sun and ground, but exposed to zenith and northern sky.			C. Thermometers screened from sun and ¾ sky.			D. Complete shade of louvre-boards under shed.			Cloud.		Wind.
		Large bulb.	Ord.	Black bulb.	Large bulb.	Ord.	Black bulb.	Large bulb.	Ord.	Black bulb.	Ord.	Black bulb.	Wet.	Amount.	Character.	Hourly Velocity.
		°	°	°	°	°	°	°	°	°	°	°	°			miles
Sept. 3, 1.25 P.M.	2	83·3	81·1	87·0	79·0	78·6	79·3	79·1	78·4	79·3	77·1	77·1	67·3	3	cir.	23
,, 3, 2 P.M.	1	82·7	80·0	85·0	77·8	77·3	78·1	78·2	77·4	78·1	76·8	76·9	66·1	5	cir.	23
,, 3, 2.15 P.M.	1	84·0	81·5	87·5	79·3	78·6	79·7	79·4	78·7	79·7	77·6	77·6	67·4	3	cir.	23
,, 4, 1 P.M.	1	77·5	75·5	79·5	73·3	72·9	73·9	73·9	73·2	73·9	72·6	72·6	66·9	6	cir. s.	11
,, 4, 1.30 P.M.	1	78·4	76·8	83·8	73·8	73·1	74·6	73·9	73·4	74·1	72·4	72·4	66·9	6	cir. s.	11
Mean of 5 observations ...	...	81·18	78·98	84·56	76·64	76·10	77·12	76·90	76·22	77·02	75·30	75·32	66·92	4·6	...	18·2

Table IV. Sky nearly Overcast.

Sept. 4, 10.30 A.M.	2	73·0	71·7	74·4	73·2	72·1	74·0	71·7	71·2	71·9	70·6	70·6	66·1	10	cir. c. & cir. s.	14
6, 12.35 P.M.	1	69·0	68·0	69·8	69·3	68·6	70·1	68·9	67·4	68·4	67·3	67·3	60·5	8	cum.	21
8, 1 P.M.	1	62·3	61·5	63·0	63·3	62·6	64·1	63·4	61·9	62·6	60·9	60·9	53·9	10	cir. c.	17
,, 12, 3.30 P.M.	1	[69·0]	68·0	69·5	69·3	68·1	69·6	69·1	68·7	69·3	68·1	68·1	63·5	9	cum.	19
Mean of 4 observations ...	...	68·42	67·30	69·18	68·78	67·85	69·45	68·28	67·30	68·05	66·72	66·72	61·00	9·2	...	17·7

TABLE V. Extremes registered by Maximum Thermometers.

Date.	A. Thermometers exposed to full sun.			E. Thermometers exposed to full sun, but with zenith sheltered.			B. Thermometers screened from sun and ground, but exposed to zenith and northern sky.			C. Thermometers screened from sun and from ¾ sky.			D. Complete shade of louvre-boards under shed.	
	Black bulb *in vac.*	Black bulb	Ord.	Black bulb *in vac.*	Black bulb	Ord.	Black bulb *in vac.*	Black bulb	Ord.	Black bulb *in vac.*	Black bulb	Ord.	Black bulb *in vac.*	Ord.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°
Sept. 5, 11 A.M.	119·0	86·8	74·2	119·0	85·6	74·7	75·0	72·0	70·0	75·7	72·5	71·7	69·0	69·3
„ 5, 1.30 P.M.	125·5	86·8	77·0	123·8	86·6	76·7	80·5	75·3	72·3	79·0	74·8	74·2	70·8	70·7
„ 6, 12.35 P.M.	124·0	83·0	72·8	122·5	84·1	74·7	74·2	72·5	70·0	77·6	73·0	72·7	70·3	69·1
„ 8, 4 P.M.	121·0	81·3	70·2	114·5	85·1	72·7	79·5	74·0	66·3	72·8	69·3	68·5	64·8	64·9
„ 10, 4 P.M.	125·5	77·8	70·0	115·8	79·1	69·2	84·5	72·7	68·8	73·0	70·0	69·2	65·6	66·0
„ 12, 4 P.M.	119·0	82·8	75·2	116·0	83·1	75·7	85·5	76·0	71·8	77·8	74·8	74·2	70·8	70·9
„ 13, noon	122·8	83·3	74·2	118·0	85·1	75·2	80·0	77·7	72·8	79·5	76·6	75·7	70·8	71·8
„ 13, 12.20 P.M.	124·2	83·8	75·2	120·0	86·1	76·2	83·0	78·0	73·3	80·5	77·3	76·7	72·3	73·1
„ 13, 1.20 P.M.	122·0	84·8	76·4	117·0	86·3	77·7	86·0	78·3	75·0	80·0	77·8	77·0	73·0	73·7
„ 13, 3.25 P.M.	129·0	87·6	78·7	123 2	87·6	79·2	92·0	80·3	76·8	83·5	79·8	79·1	75·0	75·0
Mean of 10 observations ...	123·20	83·80	74·39	118·98	84·87	75·20	82·52	75·68	71·71	77·92	74·59	73·90	70·24	70·45

TABLE VI. Similar Thermometers under Different Conditions of Exposure.

Exposed to	1. Ground and ½ sky.	2. ½ sky and not ground.	3. Ground and not sky.	4. Neither.	5. In louvre-board screen.
Cloud 5 or more ...	°	°	°	°	°
	60·6	60·4	60·2	59·8	59·5
	63·0	62·3	62·5	61·8	61·6
	53·0	52·4	53·2	52·4	52·3
	51·3	51·0	51·0	50·7	50·6
	53·7	52·9	53·5	52·3	52·3
	56·0	55·1	55·9	54·4	54·1
	56·27	55·68	56·05	55·23	55·07

Exposed to	1. Ground and ½ sky.	2. ½ sky and not ground.	3. Ground and not sky.	4. Neither.	5. In louvre-board screen.
Cloud less than 5 ...	°	°	°	°	°
	51·6	51·1	52·0	50·9	50·9
	54·2	53·6	54·5	53·7	53·1
	45·8	45·1	45·9	45·0	44·9
	51·4	51·0	51·5	50·9	50·6
	50·8	50·1	51·0	50·1	50·3
	52·3	51·8	53·0	52·1	52·1
	51·5	50·9	52·0	50·7	50·1
	51·09	50·51	51·41	50·49	50·29

The discussion on this paper will be found at p. 172.

XVIII. *Remarks on the "Pocky" Cloud observed July 27th*, 1872.

By J. S. HARDING, F.M.S.

[Received December 18, 1872. Read January 15, 1873.]

IT may be interesting to know that I observed a very fine specimen of the "Pocky" cloud at Havre, on Saturday, the 27th of July last. The day had been very fine and hot; but between 4^h and 5^h P.M. the sky became quickly overcast; and from 5^h to 6^h P.M. the place was visited by a heavy thunderstorm, the wind blowing very strongly in gusts.

So far as the rain was concerned, I do not remember having seen any thing to equal it before. I was staying in the Grande Rue, one of the widest streets of the town, and being situated at the foot of high hills, in a few minutes it became like a river, the water reaching almost to the horses' knees in some parts.

By about 6^h 30^m P.M. the storm had entirely passed, and on going out I at once observed that nearly all the sky, excepting near the horizon, was covered with the peculiar clouds in question.

The cloud very much resembled the illustration given in the 'Journal of the Meteorological Society' for 21st of February last, excepting that the festoons appeared to be much larger and more decided, and not so closely